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EFFECTS OF HEAD IMPACT ACCELERATION ON HUMAN
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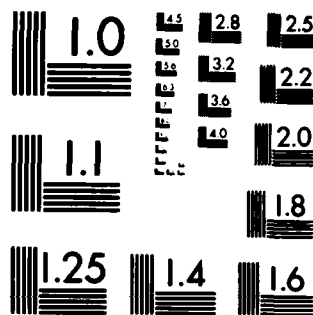
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EFFECTS OF HEAD IMPACT ACCELERATION ON HUMAN PERFORMANCE:
OVERVIEW AND PRELIMINARY BATTERY IDENTIFICATION

Alvah C. Bittner, Jr., James P. Shortal, III, and Mary M. Harbeson



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A review of the human performance effects of impact acceleration was conducted as part of an effort to assemble an experimental test battery. Tasks were designated for inclusion only if suitable for repeated measures applications and sensitive to closed-head impact acceleration. Two human performance tasks which met these criteria were identified after separate reviews of experimental and clinical research. In addition, three tasks sensitive to impact effects and <u>potentially</u> suitable for repeated measures applications were also identified. A third category of tasks which are suitable for repeated measures		

research but have not yet been shown to be sensitive to impact acceleration have been identified in other reports from this laboratory, but are beyond the scope of the present study. Short-term Consonant Memory, Adaptive Serial Addition, and Adaptive Visuospatial Judgement tasks were determined to be sensitive candidate measures with potential for repeated measures applications and were recommended for development. Choice Reaction Time (CRT) and Manikin Spatial Orientation Tasks were recommended for inclusion in an impact acceleration test battery for current applications.

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SUMMARY PAGE

PROBLEM

A review of the human performance effects of impact acceleration was conducted as part of an effort to assemble an experimental test battery. Tasks were designated for inclusion only if suitable for repeated measures applications and sensitive to closed-head impact acceleration.

FINDINGS

Two human performance tasks which met these criteria were identified after separate reviews of experimental and clinical research. In addition, three tasks sensitive to impact effects and potentially suitable for repeated measures applications were also identified. A third category of tasks which are suitable for repeated measures research but have not yet been shown to be sensitive to impact acceleration have been identified in other reports from this laboratory, but are beyond the scope of the present study.

RECOMMENDATIONS

Short-Term Consonant Memory, Adaptive Serial Addition, and Adaptive Visuospatial Judgement tasks were determined to be sensitive candidate measures with potential for repeated measures applications and were recommended for development. Choice Reaction Time (CRT) and Manikin Spatial Orientation Tasks were recommended for inclusion in an impact acceleration test battery for current applications.

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INTRODUCTION

Closed-head impact acceleration which may occur under a variety of escape and survival situations can result in stunning, confusion, and performance decrements (Benton, 1979; Ewing, 1982; Snyder, 1970; Taylor, 1963). Vehicle crashes, aircraft ejection, parachute opening, and blast shock-waves are well-known sources of abrupt onset, short duration (<1.0 s), high magnitude impact forces (Synder, 1973; Reid, Doerr, Dashier, & Ellerston 1971). Escape and survival may, because of impact-related performance disruptions, be severely compromised as pointed out in 1964 by Ewing (cf., Ewing & Unterharnscheidt, 1976; Reader, 1979; Unterharnscheidt, 1983). Recent evidence suggests that even minor closed-head injuries may result in persistent performance decrements (Rimel, Giordani, Barth, Boll, & Jane, 1981). Human performance disruptions caused by impact acceleration are the focus of the present investigation.

Background

The present study is part of a major research program at the Naval Biodynamics Laboratory (NBDL) directed at investigating the biomechanical, physiological, and behavioral effects of impact of the head and neck (Ewing & Thomas, 1971, 1972; Ewing, Thomas, Sances, & Larson, 1983). In contrast to direct impact acceleration such as collision of the head with other objects, indirect impact acceleration is the primary focus of this program. Indirect impact acceleration is that which is transmitted between two parts of a body via a link (e.g., from the torso to the head via the neck). The ultimate goal of this research is the development of mathematical and engineering models which predict injuries of the head and neck. It is believed that such predictions would provide guidance toward reduction of the more than eight million head and neck injuries expected annually in the United States (National Safety Council, 1979; Rimel, et al., 1981; Sances, Weber, Larson, et al., 1981).

Part of the NBDL modeling effort involves the use of transient evoked potential (EP) disruptions as predictors of impending central nervous system damage in Rhesus (Saltzberg & Burton, 1979; Berger & Weiss, 1983; Weiss & Berger, 1982). Specifically, significant transient increases in the peak latency of cervical and cortical somatosensory evoked potentials (SSEPs) occurred with sled accelerations above 600 m/s^2 , while gross neuropathological damage occurred at levels of acceleration exceeding 720 m/s^2 (Unterharnscheidt, 1983). Transient reduction in the amplitude of the cortical SSEPs occurred as a linear function of the level of frontal impact ($-X$) acceleration with 50% to 100% reduction at accelerations above 600 m/s^2 . Preliminary results in humans also indicate linearly increasing changes in short latency SSEPs over $-X$ accelerations between 50 and 150 m/s^2 (Seales, Bittner, Weiss, & Morrill, 1982). The parallel between Rhesus and human EP results suggests that they could be used for predicting levels of impact acceleration which occasion human neuropathological damage. A second part of the NBDL research effort is aimed at determination of performance disruptions which, in addition to implications for compromised escape and survival, may be used for prediction of impact levels which occasion neuropathological damage. Prediction of human performance disruptions and injuries is a goal of the research program at NBDL.

Purpose

The primary goal of this study was to identify candidate tasks which have been demonstrated to be sensitive to impact acceleration effects on human performance. A secondary goal was to select from the sensitive tasks, those tasks which might also be expected to be statistically suitable for repeated measures applications. A third category of tasks which are suitable for repeated measures research but have not yet been shown to be sensitive to impact acceleration have been identified in other reports from this laboratory, but are beyond the scope of the present study (Bittner, Carter, Kennedy, Harbeson, & Krause 1983; Kennedy, Bittner, Carter, Krause, Harbeson, McCafferty, Pepper, & Wiker, 1981; Harbeson, Bittner, Kennedy, Carter, & Krause, 1983). Overall, the purpose of this study was to assemble a preliminary battery of impact sensitive human performance tasks for use in an experimental indirect impact acceleration program.

METHOD AND RESULTS

Selection of performance tasks was conducted in two phases. Candidate experimental and clinical tasks were identified in the first phase and task selection was conducted in the second. These two phases will be taken up in turn.

Identification of Candidate Tasks

The strategy in this phase was to collect the experimental and clinical information most relevant to impact acceleration effects upon human performance. The experimental literature relating performance and impact acceleration was viewed as of greatest relevance. However, the paucity of such literature suggested over-viewing the clinical literature where undifferentiated mixes of direct and indirect impact are the rule. Excluded from consideration were sustained acceleration studies which largely reflect the effects of slow displacement of blood away from the head (Gillingham & McNaughton, 1977). The effects of direct and indirect impact would be expected to differ from sustained acceleration because of their higher rates of onset, briefer duration, and higher peak accelerations (Unterharnscheidt, 1983). Also excluded were reports of concussion related physiological changes which resulted as part of experimental studies such as those reviewed in Snyder (1970, 1973). Lastly, excluded were clinical reports of the effect of closed head injuries on personal or social functioning which were beyond the scope of the present experimental program (e.g., Benton, 1979; Levin & Grossman, 1978; Rimel et al., 1981). Only clinical findings relating to closed-head impact injuries were included in the review. It was noted, however, that there were possible relationships between impact and electroconvulsive shock effects (Govens, Govens, Van Huss, & Heunser, 1972). The search strategy was designed to focus on only the most directly pertinent experimental and clinical research.

Experimental and clinical information searches were conducted in two stages. In the first stage, personnel currently or previously active in experimental impact investigations (at this and other laboratories) were queried; this strategy identified both a network of researchers and several important resources (e.g., Snyder, 1970, 1973; Reader, 1975, 1979). The second stage utilized manual and computer searches of literature bases:

PSYCHINFO; National Technical Information Service (NTIS); and the Social Science Citation Index (SSCI). The manual and computer based literature searches, while identifying clinical resources, uncovered no experimental research which had not been revealed by personal communication.

Following the literature search, selected extracts of experimental and clinical reports were prepared in tabular format. The format for the experimental reports emphasized experimental features including: impact forces, tasks, results, and comments. Clinical studies collected as part of the overview were placed into seven functional categories ranging from Visuospatial Judgment to Verbal Associative Fluency. Tasks in each functional category were described with results indicating their sensitivities. Clinical tasks were selected as representative of the respective functional areas, and were largely drawn from a list of recommended tasks (Benton, 1979, 1982). Tables 1 and 2 present summaries of the prospective experimental and clinical tasks considered in subsequent analyses.

Selection of Tasks

The primary goal of this phase was to identify sensitive candidate tasks suitable for repeated measures applications in an experimental impact program. Pertinently, only sensitive tasks suitable for repeated measures may be meaningfully used for long term follow up and other (e.g., rehabilitation) studies (Bittner, Lundy, Kennedy & Harbeson, 1982; Carter, Stone & Bittner, 1982). Candidate tasks were identified as suitable when literature indicated that analogous or isomorphic tasks had previously been found to have met appropriate statistical criteria. In general, the statistical characteristics considered necessary were: (1) the means change in a linear manner or are level over trials; (2) variances are homogeneous over trials; (3) cross-trial correlations are differentially stable (constant); and (4) reliability is at an acceptably high level (Bittner & Carter, 1981). It is noteworthy that more than six dozen tasks have been evaluated in terms of these criteria as part of the Performance Evaluation Tests for Environmental Research (PETER) Program (Bittner, et al., 1983; Kennedy, et al., 1981; Harbeson, et al., 1983). Approximately one third of these tasks were found to be suitable for repeated measures testing, but only those which had also been shown to be sensitive to closed-head impact injury were considered in this report. Experimental and clinical tasks were evaluated sequentially for sensitivity and suitability for repeated measures.

Experimental Tasks. Table 1 contains the only two tasks which have been found experimentally sensitive and suitable for repeated measures applications. The first of these was Choice Reaction Time (CRT) which consisted of 1-, 2-, and 4-choice subtasks. Individual subtasks might be expected to become stable after about 300 trials, as the three subtasks in combination were found suitable after 1000 practice trials by Krause and Bittner (1982). It is important to note that CRT requires subjects to respond differentially to two or more stimuli and might be expected to be similar to the task reported by Frolov (1966). CRT yields two scores related to differing parts of the task: Reaction Time (RT) and Movement Time (MT). The former, RT is considered most related to central processing while the latter, MT measures the time for manual movement and response. Either of these components may be disrupted by impact acceleration. Pertinently, Unterharnscheidt (1983) presents neuropathological results which suggest that manual responses may be particularly disrupted for -X impacts; this suggests paying particular attention to the MT component. In addition to other

positive features, CRT appears very similar in structure to the target choice component of the Reader (1975, 1979) tracking task. Overall, the experimental and associated literature support the use of CRT.

The Manikin task is the second experimental task which has been described as stable over repeated measures (Reader, Benel, & Rahe, 1981; Carter & Woldstad, 1983). This task requires subjects to identify which hand of a pictured, rotated human figure contains a target symbol; it has been reported as a measure of mental rotation or spatial orientation. Spatial orientation is the ability to perceive spatial patterns or to maintain orientation with respect to objects in space (Ekstrom, French, Harman, & Derman, 1976). Recently, Carter and Woldstad (1983) have reported that transformed (log.) latency scores on the Manikin test were suitable after approximately 180 trials of practice. Thus, CRT and Manikin both appear suitable experimental tasks for selection to an impact acceleration test battery.

Clinical Tasks. Table 2 contains one task demonstrated as suitable for repeated measures and shown sensitive in clinical research: Choice Reaction Time (CRT). CRT was also identified in the analysis of experimental tasks as described in the last section. Table 2 also delineates several functional measures which appear easily adaptable for repeated measures applications (e.g., Visuospatial Processing). Unfortunately, these tasks are not analogous to measures previously found stable and currently may not be selected under the guidelines of this study. These tasks could, however, be recommended subsequent to demonstration of their suitability for repeated measures applications. In addition to tasks with potential, Table 2 outlines several functions which would appear very difficult to reformulate for repeated measures applications (viz., Visuoceptive Abilities, Verbal Associative Fluency, and Visuoconstructive Abilities). Table 2 does not include the assessment of two functional areas, Immediate and Remote Memory. Benton (1979) noted equivocal results for the former, and the latter had been investigated in only one study (Levin, Grossman, & Kelly, 1977a). CRT is the only clinical measure which currently meets the criteria for selection to a test battery although several others have potential.*

DISCUSSION AND CONCLUSIONS

This investigation was motivated by the requirement for assembling a battery of tasks sensitive to the performance effects of impact acceleration. Evaluation of experimental and clinical information related to impact effects revealed two measures which were both sensitive and suitable for repeated measures: Choice Reaction Time (CRT) and Manikin. Several other functional tasks were also identified from the clinical literature as having potential for development as repeated measures instruments, but would require demonstrations of statistical suitability before they might be included. The following sections will briefly consider tasks suitable for development and provide recommendations and conclusions.

*Since the completion of the present study, Carter, Styer, and Curley (1983) have reported the development of a word fluency task which is suitable for limited repeated measures applications. The utility of their results is under study because of clinical sensitivities shown by measures of Verbal Associative Fluency (e.g., Levin, Grossman, & Kelly, 1976a).

Tasks Suitable for Development

Three tasks appear suitable for repeated measures development. In order of judged promise, these represent functions of (1) Short-Term Recognition Memory, (2) Serial Information Processing, and (3) Visuospatial Judgement. A Short-Term Recognition Memory task is currently being developed at NBDL. This task begins by displaying ten consonants to a subject at a fixed rate under computer control. Subsequent to an intervention, twenty consonants are presented, and the subject is asked to indicate whether each letter has or has not been previously displayed. Evaluation of this task for suitability for repeated measures is later planned using the approach outlined by Bittner and Carter (1981). A Serial Addition task, as outlined in Table 2, appears potentially implementable as a repeated measures task. Based on the pacing effects reported by Gronwall (1977), a computer controlled adaptive paced task would appear to have great promise (Benton, 1982). The Visuospatial Judgement function also appears suitable for repeated measures assessment with the adaption Benton's (1975, 1978) Angle Judgement task. As indicated in Table 2, an adaptive presentation speed would provide a more sensitive measure of efficiency. Computer controlled versions of the Visuospatial Judgement task and the paced Serial Addition task appear to have substantial potential for development. Altogether, computer controlled versions of Short Term Consonant Memory, Adaptive Serial Addition, and Adaptive Visuospatial Judgement appear to hold promise as performance tasks for impact acceleration research.

Recommendations and Conclusions

It is recommended that Short-Term Consonant Memory, Adaptive Serial Addition, and Adaptive Visuospatial Judgement tasks be developed and evaluated as potential tasks for assessment of the effects of impact acceleration on performance. For current applications, it is concluded that the Choice Reaction Time (CRT) and Manikin Spatial Orientation Tasks should be included in a preliminary battery to assess the effects of impact acceleration on human performance.

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TABLE 1: SUMMARY OF EXPERIMENTAL STUDIES OF IMPACT ACCELERATION AND HUMAN PERFORMANCE

AUTHOR	IMPACT FORCE	TASK	RESULTS	COMMENTS
TAYLOR (1963)	10 TO 25 $-G_x$	KAHN SYMBOL ARRANGEMENT TEST [SUBJECT ARRANGES 16 PLASTIC OBJECTS IN FIVE ARRANGEMENTS - FIRST TWO AS WISHED, THIRD EXACTLY AS SECOND, FOURTH IN ORDER OF PREFERENCE AND FIFTH AGAIN AS WISHED. SCORE IS BASED ON VERBALIZATIONS OF OBJECT NAMES, REASONS FOR ARRANGEMENTS, LINKINGS AND DISLIKINGS]	REPORTS SHOWED DISTINCTIVE CHANGES WITH FORCE LEVEL.	TASK IS OF COMPLEX NATURE AND RATIONALE OF CONSTRUCTION AND VALIDATION IS NOT SATISFACTORY (JESSOR, 1959).
FROLOV (1966 AS CITED IN READER, 1975)	$-G_x$	REACTION TIME TASK TO LIGHT STIMULI MEASURED POST IMPACT	REACTION TIME INCREASED WITH INCREASING FORCE OF IMPACT	TASK IS BELIEVED TO HAVE BEEN CHOICE REACTION TIME (READER, 1982). [COPIES OF THE ORIGINAL REPORT WERE NOT FOUND DESPITE SEARCH OF SEVERAL SOURCES. SNYDER (1970, 1973) DOES NOT MENTION STUDY.]
READER (1975; 1979)	0 [SHAM] TO 12.5 $-G_x$	DISCRETE TRACKING TASK DEvised BY GIBBS (1966) [A SPOT OF LIGHT OCCURS AT ONE OF 5 POSITIONS IN RANDOM ORDER; THE SUBJECT CONTROLS, VIA A HAND CONTROLLER, A VERTICAL CURSOR WHICH MUST OCCLUDE A SPOT FOR 200 MS BEFORE NEW SPOT POSITION IS SELECTED. SCORES INCLUDED: TIME TO INITIATE MOVEMENT WITH SPOT OCCURRENCE (LATENCY); PERIOD OF MOVEMENT TILL SPOT OCCLUDED (MOVEMENT TIME); AND NUMBER OF OCCLUDED SPOTS (HITS).]	HITS WERE DECREASED RELATIVE TO CONTROLS: -2.5 AT 0 (SHAM) $-G_x$, -2.3 AT $5.3 -G_x$, -6.3 AT $10.6 -G_x$ AND -14.2 AT $12 -G_x$. LATENCY AND MOVEMENT TIME COMPONENTS ALSO SHOWED TREND BUT WERE STATISTICALLY NON-SIGNIFICANT.	
READER (1982)	0 [SHAM] TO 12.5 $-G_x$	FOLLOWING MANIKIN SPATIAL ORIENTATION TASK DEvised BY BENSON AND GEDYE (1963). [SUBJECT REQUIRED TO INDICATE HAND (LEFT OR RIGHT) HOLDING TARGET AS PICTURED MANIKIN IS RANDOMLY POSITIONED: UPSIDE-DOWN VS UPRIGHT AND FRONT VIEW VS REAR VIEW]	SCORES DECLINED WITH INCREASES IN G LEVEL FOLLOWING RELATIONSHIP OF READER (1975, 1979)	TASK APPEARED TO BE MORE SENSITIVE THAN DISCRETE TRACKING AS INFORMALLY REPORTED BY READER (1982).

TABLE 2: OVERVIEW OF THE CLINICALLY OBSERVED EFFECTS OF CLOSED HEAD IMPACT INJURIES

FUNCTION	TASKS	RESULTS	COMMENTS
VISUOSPATIAL JUDGEMENT	VISUOSPATIAL JUDGEMENT (BENTON, 1978, 1979). RESPONSE CHOICE DISPLAY OF LINES SEPARATED BY 18° ANGLES ARE SHOWN. INDIVIDUAL STIMULUS CONSISTS OF 2 LINES FROM THIS DISPLAY. TASK IS TO INDICATE THE 2 LINES IN THE DISPLAY THAT HAD THE SAME ANGLES AND OCCUPIED THE SAME LOCATION AS THE 2 STIMULUS LINES. TEST TIME IS 6-10 MINUTES.	SENSITIVE TO RIGHT HEMISPHERE INJURY. PATIENTS WITH LEFT HEMISPHERE DISEASE PERFORM COMPARABLE TO A CONTROL GROUP.	BENTON (1982) COMMENTS THAT A TEST INCLUDING AN ADAPTIVE PRESENTATION SPEED WOULD PROVIDE A MORE SENSITIVE MEASURE OF VISUOPERCEPTIVE EFFICIENCY. BOOK FORM OF TEST IS CURRENTLY AVAILABLE.
SHORT-TERM RECOGNITION MEMORY	VISUAL CONTINUOUS RECOGNITION TEST (BROOKS, 1974a,b; KIMURA, 1963). SUBJECT IS SHOWN A SET OF 20 CARDS WITH DESIGNS ON EACH (HALF ARE GEOMETRIC, HALF ARE "NONSENSE" AND HARD TO VERBALLY ENCODE). SUBJECT IS TOLD TO DETERMINE IF EACH OF THE NEXT 20 CARDS (7 SETS OF THESE) IS "NEW" (1ST APPEARANCE) OR "OLD" (A RECURRENCE). 8 CARDS REAPPEAR IN ALL SETS.	HEAD INJURED PATIENTS SHOWED A SIGNIFICANTLY LOWER MEMORY CAPACITY, AND A SIGNIFICANTLY HIGHER DEGREE OF CAUTION (VERY UNWILLING TO GUESS). LEVEL OF FALSE NEGATIVES (FAILURE TO IDENTIFY A RECURRING SHAPE) IS SIGNIFICANTLY HIGHER IN HEAD-INJURED PATIENTS (REGARDLESS OF SEVERITY OF INJURY). OLDER PATIENTS SHOWED A MORE SIGNIFICANT RELATIONSHIP BETWEEN POST TRAUMATIC AMNESIA (PTA) AND MEMORY SCORE THAN YOUNGER PATIENTS.	UNDERLYING NATURE OF DEFECIT UNCLEAR (COULD BE LEARNING DEFICIT, UNWILLINGNESS TO GUESS, OR BOTH). SEVERITY OF MEMORY DEFICIT WAS RELATED TO LENGTH OF PTA, BUT NOT TO NEUROLOGICAL SIGNS AT TIME OF TESTING, NOR TO TIME AFTER INJURY TO TESTING. SIGNAL DETECTION THEORY (BROOKS, 1974b) IS VERY DISCRIMINATING IN DETERMINING TRUE MEMORY CAPACITY VS. DEGREE OF CAUTION USED BY SUBJECT.
	FORCED CHOICE SHAPE RECOGNITION TEST (LEVIN, GROSSMAN, & KELLY, 1976b). SUBJECT IS SHOWN A DESIGN (21 RANDOM SHAPES, OF LOW, MEDIUM, AND HIGH ASSOCIATIVE VALUES) FOR 20 SECONDS FOLLOWED BY A "BLANK" INTERVAL OF EQUAL DURATION AFTER WHICH HE WOULD BE ASKED (FORCED CHOICE) TO RECOGNIZE THE ORIGINAL DESIGN ON A FOUR-ALTERNATIVE DISPLAY.	SEVERITY OF HEAD INJURY WAS CLOSELY RELATED TO IMPAIRMENT IN PERFORMANCE. DISRUPTION OF SHORT-TERM RECOGNITION MEMORY WAS ASSOCIATED WITH NEUROLOGIC DEFICIT, APHASIC DISTURBANCE, AND SIGNS OF BRAIN STEM INVOLVEMENT.	TEST SHOWS AN IMPAIRMENT IN RECOGNITION MEMORY OVER AN EXCEEDINGLY BRIEF RETENTION INTERVALS IN SOME PATIENTS, COMPARED TO A CONTINUOUS RECOGNITION TEST. THIS TEST SUGGESTS THAT SHORT-TERM RECOGNITION MEMORY IS LESS VULNERABLE TO HEAD INJURY THAN IS RECOGNITION MEMORY SPANNING LONGER INTERVALS.

TABLE 2 (CONTINUED)

FUNCTION	TASKS	RESULTS	COMMENTS
VISUOPERCEPTIVE ABILITIES	FACIAL RECOGNITION TEST (BENTON & VAN ALLEN, 1968). SUBJECT IS TO MATCH IDENTICAL FACIAL PHOTOGRAPHS (STARTING WITH IDENTICAL FRONTAL PHOTOGRAPHS, THEN MATCHING A FRONTAL PHOTOGRAPH WITH EITHER A 3/4 VIEW PHOTOGRAPH, OR 3 OTHER FRONTAL PHOTOGRAPHS TAKEN UNDER VARYING LIGHT CONDITIONS). MULTIPLE CHOICE DISPLAY ON EACH TRIAL IS 6 PHOTOGRAPHS. STIMULUS AND MULTIPLE-CHOICE DISPLAYS ARE PRESENTED SIMULTANEOUSLY. STUDY CITED IN LEVIN, GROSSMAN, & KELLY, 1977b).	SEVERITY OF HEAD INJURY WAS INVERSELY RELATED TO ACCURACY OF PERFORMANCE. IMPAIRMENT OF FACIAL RECOGNITION WAS SPECIFICALLY ASSOCIATED WITH SIGNS OF CONCOMITANT HEMISPHERIC AND BRAIN STEM INJURY.	THIS TEST MEASURES VISUOPERCEPTIVE ABILITIES WHILE POSTING MINIMAL DEMANDS ON MEMORY PROCESSES. TEST IS SENSITIVE TO EFFECTS AFTER CLINICALLY SEVERE INJURIES BY DETECTING LOW PERFORMANCES AS LATE AS ONE YEAR POST INJURY.
SERIAL INFORMATION PROCESSING	PACED SERIAL ADDITION TASK (GRONMALL, 1977). SUBJECT IS PRESENTED DIGITS AT A CONSTANT RATE (2.8, 2.4, 1.6, OR 1.2 PER SECOND). SUBJECT IS REQUIRED TO ADD THE 1ST TWO DIGITS, ANNOUNCE THE SUM, THEN ADD THE 3RD DIGIT PRESENTED TO THE 2ND AND DECLARE THE SUM, ETC.	EVEN MILDLY CONCUSSED PATIENTS SHOWED DEFECTS IN PERFORMANCE UNDER FIXED PACING CONDITIONS, WHILE THEIR PERFORMANCE UNDER AN UNPACED CONDITION WAS USUALLY WITHOUT ERROR.	THIS IS A MULTIPLE COMPONENT TASK SENSITIVE TO SLOWING IN THE SPEED OF PROCESSING. SLOWING COULD BE DUE TO DISRUPTION OF SPECIFIC TASK COMPONENTS OR TO DELAYED SWITCHES BETWEEN COMPONENTS.
CHOICE REACTION TIME	CHOICE REACTION TIME TASK (MILLER, 1970; GRONMALL, & SAMPSON, 1974). SUBJECT IS PRESENTED WITH A THREE-VALUED STIMULUS AND IS INSTRUCTED TO IDENTIFY THE PRESENTED STIMULUS FROM AMONG THE 3 CHOICES.	SIMPLE REACTION TIME IS NOT RETARDED IN POSTTRAUMATIC PATIENTS, WHILE CHOICE REACTION TIME INVOLVING THE CENTRAL PROCESSING OF INFORMATION AND SELECTION OF ONE OF A NUMBER OF ALTERNATIVE RESPONSES DOES DISCRIMINATE BETWEEN POSTTRAUMATIC PATIENTS AND CONTROLS.	KRAUSE & BITTNER (1982) HAVE SHOWN SIMILAR TESTS SUITABLE FOR REPEATED MEASURES AFTER 300 TRIALS PRACTICE.

TABLE 2 (CONTINUED)

FUNCTION	TASKS	RESULTS	COMMENTS
VERBAL ASSOCIATIVE FLUENCY	<p>OBJECT NAMING (SMITH, 1974). SUBJECT IS PRESENTED WITH OUTLINE DRAWINGS OF OBJECTS FALLING AT VARIOUS WORD FREQUENCY RANGES (I.E., THORNDIKE-LORGE, 1963). TWO MEASURES TAKEN ARE: NUMBER OF ITEMS CORRECTLY NAMED, AND TIME (IN MILLISECONDS) TO NAME EACH ITEM (LATENCY). SPEED IS EMPHASIZED, AND LATENCIES GREATER THAN 4 SEC ARE DEEMED FAILURES.</p>	<p>RIGHT-IMPACT PATIENTS PERFORM AT A SIGNIFICANTLY LOWER LEVEL OF EFFICIENCY ON ALL VERBAL TESTS THAN LEFT-IMPACT PATIENTS.</p>	<p>TEST RESULTS FROM SMITH (1974) SHOW THAT IMPACT ON THE RIGHT HEMISPHERE PRODUCES GREATER DISRUPTION OF COGNITIVE ABILITIES. STUDIES INDICATE THAT THE LEFT HEMISPHERE PLAYS THE MAJOR PART IN THE SYNTHESIS OF VERBAL BEHAVIOR AND THAT THE RIGHT HEMISPHERE IS CONCERNED WITH THE INTEGRATION OF VISUOSPATIAL INFORMATION (DARLEY, 1967; MILNER, 1964).</p>
	<p>MECHSLER LOGICAL SEQUENCES (SMITH, 1974). TWO SHORT STORIES FROM THE MECHSLER MEMORY SCALE (1958) ARE READ TO THE SUBJECT WHO HAS TO RECALL AS MUCH AS POSSIBLE FROM EACH PASSAGE. AN HOUR LATER (WITHOUT WARNING), SUBJECT IS AGAIN ASKED TO RECALL AS MUCH AS POSSIBLE FROM THE STORIES.</p>	<p>SECOND REPETITION OF STORIES FROM MECHSLER LOGICAL SEQUENCES TEST MEASURES DELAYED VERBAL RECALL.</p>	<p>SEE ABOVE</p>
VISUOCONSTRUCTIVE ABILITIES	<p>TASKS INCLUDE NAIS BLOCK DESIGNS, OBJECT ASSEMBLY, THREE DIMENSIONAL BLOCK CONSTRUCTION, STICK CONSTRUCTION (BENTON, 1979).</p>	<p>MORE SEVERE AND MORE FREQUENT CONSTRUCTIONAL DISABILITY IS FOUND IN PATIENTS WITH RIGHT-HEMISPHERE DISEASE.</p>	<p>THESE TASKS ARE DIFFICULT TO IMPLEMENT IN REPEATED MEASURES.</p>

